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COLORADO GEOLOGICAL SURVEY
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R. D. GEORGE, State Geologist

BULLETIN 22

MINERAL DEPOSITS OF THE WESTERN SLOPE

BY
H. A. AURAND

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DENVER, COLORADO

GEOLOGICAL BOARD

His Excellency, Oliver H. Shoup.....Governor of Colorado
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LETTER OF TRANSMITTAL

State Geological Survey,
University of Colorado, October 28, 1920.

Governor Oliver H. Shoup, Chairman, and Members of the Advisory Board of the State Geological Survey.

Gentlemen: I have the honor to transmit herewith Bulletin 22 of the Colorado Geological Survey.

Very respectfully,

R. D. George,
State Geologist.

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INTRODUCTION

The office of the State Geologist has been in almost constant communication with individuals seeking information concerning the location, occurrence, and possibilities of mineral deposits on the "Western Slope" of Colorado.

This bulletin was prepared with a view of furnishing the public with information concerning the location of these deposits. It is not exhaustive in its location of the various deposits, nor is the bibliography which accompanies the bulletin exhaustive as to the sources of information concerning the deposits.

The "Western Slope" is divided by natural barriers into three distinct districts; the Southwestern, the Western, and the Northwestern parts of the State. These barriers have so seriously impeded transportation facilities as to limit the areas which may be served by the various railroads.

The three districts are practically isolated from each other as far as railroad transportation is concerned, while the Southwestern and Northwestern parts are at times isolated from the "Eastern Slope," through heavy snows blockading the railroads on the Continental divide.

The general effect of these barriers is to not only impede transportation, but to increase the costs of transportation between the "Western and Eastern Slopes."

The question of a complete survey of the various resources cannot be taken up in a publication of this kind, while a complete bibliography of the resources would have to be published as a separate bulletin.

ACKNOWLEDGMENTS

It would be almost impossible for the writer to acknowledge the many sources from which the material incorporated in this bulletin has been gathered.

The writer feels, however, that he is deeply indebted to R. D. George for his many helpful comments, and for the advice given during the preparation of this bulletin.

Many publications have been drawn upon in seeking material, and while individual acknowledgments could not always be made, the bibliography will undoubtedly indicate the main sources from which the information was obtained.

As the literature on the mineral deposits of Colorado is scattered so widely, the various publications of the United States Geological Survey, the Colorado Geological Survey, the Colorado Bureau of Mines, and the reports of the State Coal Inspector, were used extensively.

A large amount of helpful material was also obtained from articles printed in well-known scientific publications, and from various publications of the University of Colorado and the Colorado School of Mines.

Bulletins of the Colorado Geological Survey on the Molybdenum deposits of Colorado, by P. G. Worcester; the Manganese deposits of Colorado, by G. A. Muilenburg; the Fluorspar deposits of Colorado, by H. A. Aurand, were drawn on freely for information concerning the location of deposits of those minerals.

In many instances the material taken from various publications is quoted literally, in others it is a summary or digest of the original articles or reports. In other cases a few sentences or paragraphs only are used. For the sake of convenience, most of the matter is incorporated into this report without the use of quotation marks or special acknowledgment.

CHAPTER I

MINERAL DEPOSITS OF NORTHWESTERN COLORADO

BARITE

GRAND COUNTY

Barite is reported as occurring on the Vasquez River,[1] a left branch of the Frazer River, in Grand County. No attempt has been made to ship barite from this locality.

BUILDING STONE

ROUTT COUNTY

Sandstone.—A creamy-white to pink sandstone has been quarried at Steamboat Springs. The stone was used locally for building purposes.

CLAYS

NORTHWESTERN COLORADO

In this district, there are abundant outcroppings of the Mancos formation. The shales of this formation should prove valuable in the manufacture of ordinary brick, pressed brick, soft mud brick, and coarse earthenware. Certain horizons near the base of the Mancos formation furnish clays suitable for the manufacture of either light flesh-tinted or red pressed bricks.

The Dakota and Mesaverde formations contain numerous lenticular beds of fire clay. Intelligent prospecting will doubtless lead to the discovery of a large amount of fire clay.

[1]Smith, J. Alden, Report of Colorado State Geologist for 1881-1882; p. 131, 1883.

COAL

JACKSON COUNTY

The coal beds of North Park are contained in the Coalmont formation, which is of late Cretaceous or early Tertiary age. The coal beds of greatest importance outcrop between the Michigan and Canadian rivers, and in the Coalmont district in the southwestern part of the field.

Thinner beds of relatively small extent and apparently isolated are found in the Monahan and Mitchell mines. Two other localities, one on Colorado Creek below the Clover ranch, and the other near Arapahoe Pass show relatively thin beds of small extent.

The coal of the district has been classed as sub-bituminous.

It has been estimated by Beekly[2] that the amount of coal recoverable under present mining conditions is 1,152,000,000 short tons.

During 1918, two mines in the district produced 84,504 tons of coal.

YAMPA COAL FIELD

The Yampa coal field covers an irregular area of about 1,200 square miles, lying along the center of the Yampa (Bear) River valley. The area lies west of the Park Range and north of the White River Plateau and Axial basin. The field is roughly triangular in outline, its corners being, approximately, at Lay post office, Sand Mountain, and a few miles north of Yampa.

The important coal measures of the field are found in the Mesaverde formation. The coal seams fall into three groups, each ranging through a vertical distance of from 200 to 400 feet, the several groups being separated by from 500 to 1,000 feet of barren sandstone and shale.

Like most coal fields of Colorado the Yampa field contains coals ranging from lignite to anthracite. The coals for the most part are bituminous. Some lignite is found in the Laramie formation northwest of Hayden and Craig.

Anthracite coal is found in the northern part of the district, around Pilot Knob and Wolf Mountain. The anthracite area is possibly 25 square miles in extent, with a known area of 10 square miles.

[2]Beekly, A. L., Geology and Coal Resources of North Park, Colorado: U. S. Geol. Survey Bull. 596, 1915.

During 1918, 19 mines were operated in the Yampa coal field, in Routt County.

The total output of the district during 1918 was 962,691 tons, as compared with 1,057,686 tons mined in 1917.

It seems almost certain that with more adequate transportation facilities the Yampa coal field will become an important factor in supplying the needs of the western coal markets.

DANFORTH HILLS AND GRAND HOGBACK COAL FIELD

The coal fields of the Danforth Hills and the Grand Hogback are located in the northwestern part of Colorado in Moffat, Rio Blanco, and Garfield counties. A small area is found in the western part of Pitkin County.

The Danforth Hills field lies north of White River, south of Axial Basin, west of the White River Plateau region, and east of Strawberry Creek and its extension toward the north. The Grand Hogback is a long, narrow, monoclinal ridge lying between the Grand and White rivers. It crosses the White River near Meeker and extends south and southeast crossing the Grand River at Newcastle.

A westward extension of the Danforth Hills follows along the south slopes of the Yampa Plateau and on into Utah.

The coal of the field is a good grade of bituminous. That found north of the White River is apparently similar to the coal occurring in the western part of the Yampa field. South of the White River the coal is of a somewhat higher grade than any other coal found in the northwestern part of the state, with the exception of the anthracite, occurring locally near Pilot Knob and Wolf Mountain, in Routt County.

South of the Grand River, in Pitkin County, good coking coal is found in the Gulch mine on Spring Gulch. This coal is made into coke at Cardiff. Coal from the Coalbasin mine, 12 miles west of Redstone, on a branch of Crystal River, is of a coking quality. This coal has been made into coke and shipped to the steel plants at Pueblo. Two mines were worked in Pitkin County during 1918 with a total production of 30,554 tons of coal.

The Danforth Hills area covers about 300 square miles, and is one of the most extensive coal-field units of the area. The Grand Hogback field covers an area of about 75 square miles.

Five mines were being operated in Garfield County during 1918 and the total production of the county for that year was given as 74,004 tons.[3]

During 1918 one mine was working at Axial in Moffat County. The production of coal from this mine was 548 tons.

In Rio Blanco County, three mines were operated during this same year with a production of 4,798 tons of coal.

NORTHWESTERN COLORADO

During 1907, Gale[4] made a study of the coal areas in the extreme northwestern part of Colorado, in Moffat and Rio Blanco counties. This survey showed the presence of a considerable amount of workable coal in that area.

THE UINTA COAL REGION

The great Uinta Basin stretches from the middle of Gunnison County to the southern borders of Routt and Moffat counties. In an east and west direction it stretches from the center of Gunnison County far across the state line into Utah. The Colorado part of the basin has an area of 600 square miles. The Mesaverde coal-bearing formation underlies the whole area, and its outcrops form the entire outer border of the basin. The fact that this formation is coal-bearing through this very long border is strong evidence that it is coal-bearing beneath the entire 600 square miles of the Colorado part of the basin. The studies of this basin by the geologists of the U. S. Geological Survey and by other geologists have led to this conclusion. On this basis a conservative estimate of the coal tonnage places the figure at 272,000,000,000 short tons.

The worked fields are confined to the narrow border outcrops.

The coal ranges from sub-bituminous to anthracite, and the seams, in places reach a thickness of 25 feet.

The coal tonnage of the western slope of Colorado has been estimated by the U. S. Geological Survey as follows:

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[3]Dalrymple, J., State Inspector of Coal Mines, Sixth Ann. Rept. for 1918, p. 55, 1919.

[4]Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 341, pp. 283-315, 1909.

	Short tons
Uinta region	272,000,000,000
Durango fields	21,500,000,000
Yampa fields	39,639,000,000
North Park fields	1,152,000,000
Smaller areas	500,000,000
	334,791,000,000

This is a tonnage sufficient to supply the United States, at the present rate of consumption 670 years.

COPPER

GRAND COUNTY

Some copper ore is found in the Harmon district, 12 miles southeast of Granby. The production from this district has been small. No data are available as to the production in 1919.

ROUTT COUNTY

Copper is the predominant metal in the Copper Ridge district, 9 miles northwest of Steamboat Springs; in the Slater district, 70 miles southeast of Wamsutter, Wyoming; in the Oak Creek district; the Rock Creek, or Gore Range district, 16 miles east of Yampa; in the Spring Creek district at Steamboat Springs; and in the Pearl district, 33 miles southeast of Riverside, Wyoming.

Some work has been done on a deposit of copper ore located in the extreme southeastern corner of Routt County, near the station of McCoy, on the Denver and Salt Lake Railroad.

A large deposit of copper has been reported as occurring at Douglas Mountain, in the western part of the county.

From 1873 to 1917, copper valued at $16,704 was produced in Routt County.

GOLD[5]

GRAND COUNTY

Gold occurs as the predominant metal in the ores of the Grand Lake district, 16 miles northeast of Granby, and in the La Plata district, 24 miles southeast of Granby. Only a small production has been reported from these districts.

[5]See Hill, J. M., The mining deposits of the Western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician, U. S. Geol. Survey.

MOFFAT COUNTY

Near Lay, in Moffat County, some gold has been found in placer workings. No reports are available regarding operations in this district. Placer gold is also found in the Dry Creek and Fourmile districts, in the northern part of the county.

ROUTT COUNTY

Considerable operations have been carried on from time to time in the Hahns Peak district. Placer mining, by sluicing, has been carried on in addition to lode mining. The production of gold from 1873 to 1917 totals $384,539.

SUMMIT COUNTY

During 1919, the production of gold in Summit County totaled $470,946. Gold occurs as the predominant metal in the Breckenridge, Montezuma and Swan River districts. The value of gold produced in the county from 1860 to 1917 is placed at $16,898,015.

GYPSUM

SUMMIT COUNTY

Stevenson[6] reports the occurrence of gypsiferous shales on the Snake River, (a tributary of the Blue River), in Summit County. These deposits do not appear to have any commercial value at present.

IRON

MOFFAT COUNTY

A large deposit of iron ore has been reported from the Douglas Mountain district, in the extreme western part of Moffat County. The haul of 90 miles, to the railroad at Craig, has greatly hindered the development of this deposit.

LEAD

ROUTT COUNTY

Lead predominates in the ores of the Slavonia district, 40 miles north of Steamboat Springs. No data are available concerning production in 1919.

[6]Stevenson, J. J., Geology of a portion of Colorado explored and surveyed in 1873; Wheeler Survey Rept., vol. 3, p. 374, 1875.

SUMMIT COUNTY

The ores of the Montezuma district show a predominance of lead over the other metals. This district is located 12 miles east of Dillon, and is reached from that station.

Summit County shows a lead production valued at $22,644 during 1919, and a total production valued at $6,370,510 from 1860 to 1917.

LIMESTONE

The Carboniferous formations throughout northwestern Colorado should be prospected for limestone strata. Some lime may have been burned locally, but the undertakings have never been of more than local importance.

MARBLE (Onyx)

ROUTT COUNTY

A small deposit of onyx marble is located on the south side of the Yampa, or Bear River, southwest of Steamboat Springs. The blocks of marble are somewhat limited in size, but the material is well suited for ornamental work and has been used for that purpose.

MANGANESE

MOFFAT COUNTY

It is reported that a rather extensive body of manganese and iron ore occurs on the north face of the Blue Mountains.[7] This deposit is located in the extreme northwestern part of Moffat County.

No data are available regarding the size, occurrence, or value of the deposit.

MINERAL SPRINGS

GRAND COUNTY.—Hot Sulphur Springs, pools and baths. Hotel accommodations in the town.

JACKSON COUNTY.—Mineral Springs are located 3 miles north of Cowdrey; 12 miles west of Cowdrey; 13 miles west of Walden and about 2 miles northwest of Higho. They are undeveloped.

MOFFAT COUNTY.—The Juniper Springs are improved by the building of bath houses. Hotel accommodation is available.

[7]Muilenburg, G. A., Manganese deposits of Colorado: Colo. Geol. Survey Bull. 15, p. 53, 1919.

ROUTT COUNTY.—Steamboat springs are at the town of Steamboat Springs. Bath houses, plunges, swimming pools and hotel accommodations are available.

East of Phippsburg are the Scott, Smith, and Jones Springs (undeveloped). Other springs occur in the southeastern part of the county.

SUMMIT COUNTY—Near Dillon are several mineral springs, some of which are furnished with bath houses.

MOLYBDENUM

GRAND COUNTY

It is reported that a deposit of molybdenite and molybdite (molybdenum ocher) has been found on the Grand River, one and one-half miles above the station of Radium.

ROUTT COUNTY

A property which contains some molybdenite is located on the northwest side of Little Farwell Mountain, near the head of Middle Beaver Creek. This occurrence is about five miles northeast of the town of Hahns Peak.

The molybdenite is found on both sides of a large pegmatite dike, and impregnates the country rock for several inches. The mineral occurs in grains from one-fourth of an inch up to more than one inch in diameter. Although the value of the dike as a whole is low, the presence of the molybdenite in such large grains would make the sorting of the ore extremely easy.

Several occurrences of molydenite have been reported from the Slavonia mining district. One property is located about 15 miles from Clark and is situated on the east side of a spur of the Sawtooth Range. A second property is located 10 or 12 miles from Clark on a branch of the Middle Fork of Elk River.

SUMMIT COUNTY

The largest known deposit of molybdenum ore in Colorado, and probably one of the largest in the world, is located on the Continental Divide, near Fremont Pass (Climax station), about 13 miles northeast of Leadville.

Worcester[8] describes the deposit as follows:

> "This deposit occurs in a large mineralized zone, about one mile east of the pass (Fremont) near the head of Ten-

[8]Worcester, P. G., Molybdenum deposits of Colorado: Colo. Geol. Survey Bull. 14, p. 87, 1919.

mile Creek, on the southwest slope of Bartlett Mountain and on the northwest side of Mount Ceresco. The full extent of the deposit has not yet been determined, but the surface is known to be more than one-half a square mile, and the vertical range is 500 feet and probably very much more."

The enormous amount of fracturing which the district underwent was followed by the formation of innumerable quartz veins. The country rock appears to have been chiefly a white, even-grained granite, but the alteration has been so great that even this is hard to determine.

The ore occurs as molybdenite and molybdite and is found in exceedingly small veinlets in the quartz. The whole mass of rock is more or less mineralized, and it appears that there were three periods of fracturing and vein filling; one preceded, one accompanied, and one followed the deposition of the molybdenite.

Considerable development work has been done in this area by the three companies which own, or control through leases, practically the whole mineral zone. One company had by the end of March, 1918, blocked out what is estimated as 6,000,000 tons of ore. The other companies have been developing their properties as rapidly as the market and prices paid for molybdenum would warrant.

Several deposits of molybdenite have been partially developed in the district 2 miles southeast of Kokomo. The ore in this district is very low grade, and because of the small size of the deposits they are not believed to be good.

Two molybdenum claims are located on the south slope of Quandry Mountain, about 11 miles southwest of Breckenridge.

Molybdenite has been reported as occurring on Glacier Mountain, about two miles from Montezuma; on Lenawee Mountain, near Montezuma; and near Uneva Lake.

NATURAL HYDROCARBONS

Gilsonite, or uintaite, and grahamite appear to be the only hydrocarbon minerals occurring in commercial quantities in Colorado. Other hydrocarbons, usually classed as bitumens, occur in isolated areas and in small amounts, but as they are relatively unimportant their identity has never been determined.

Although several types of hydrocarbons have been mined for years, and many others have been known to occur in Colorado,

they have not been understood, as the available literature describing them has been very limited.

The natural hydrocarbons of Colorado, as well as those of eastern Utah, appear to be confined to the Tertiary formations. In these districts the various divisions of the Eocene are noted for the number, size and variety of their asphalt veins.

The shales of the Green River formation are well known for their high bitumen content, and for the numerous strata of bituminous limestone found so widely distributed throughout the formation.

Many of the asphaltic veins, near the Colorado-Utah line, occur in fissures in the Green River formation, and in the overlying formations, especially the Bridger and Uinta. According to Osbon[9] it is surmised that the bitumens of the Green River shales are the source of the asphalts, at least, of this vast area. The variation in the ultimate material as it today fills one fissure or another is perhaps due in part to a change somewhat allied to fractional distillation in petroleum technology, and in part to the degree to which oxygen absorption has taken place.

One vein of gilsonite or uintaite is located just east of the Colorado-Utah line in Colorado. The opening on the vein is found on the crest and eastern slope of the ridge dividing Evacuation Creek from the waters running into the White River and streams farther east.

This vein has the same trend as the Bonanza vein, located just west of the Colorado line in Utah, and appears to be either a continuation of that vein, or another vein occurring in a fissure belonging to the same system. The vein may be traced on the surface for about 2 miles, and throughout shows an average width of about 30 inches. In places it has been prospected to a depth in excess of 100 feet, and according to Eldridge[10] it should continue to a depth of at least 500 feet. This vein alone should produce a tonnage of not less than 44,000 tons of high grade gilsonite.

It has been estimated by Eldridge[11] that five of the veins of gilsonite, occurring just across the state line in Utah, will produce 31,145,571 tons of marketable ore. This estimated tonnage is based on the length of the veins exposed, their average width,

[9]Osbon, C. C., Asphalt and allied substances in 1918: U. S. Geol. Survey Mineral Resources for 1918, p. 470.

[10]Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey Twenty-second Ann. Rept., pt. I, p. 354.

[11]Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey Twenty-second Ann. Rept., pt. I, p. 354.

the probable depth to which mining can economically be carried, and the depth to which the veins will probably persist.

Cowboy	14,069,250 tons
Bonanza—	
East Branch	10,434,387 tons
West Branch	4,084,497 tons
Black Dragon	2,086,479 tons
Duchesne	470,958 tons
Total	31,145,571 tons

A number of the smaller veins of the district have been prospected and some are now being worked. With this additional tonnage the district should produce in excess of 32,000,000 tons.

The gilsonite or uintaite, as it is often called, is an asphaltite, characterized by its black color, conchoidal fracture, bright luster, and red brown streak. It is marketed as "selects" or "firsts," and as "seconds." "Selects" are taken from the center of the vein while "seconds" come from near the walls.

The principal use of gilsonite is in the manufacture of paints, varnishes, and japans, where it is regarded as the best hydrocarbon for that purpose. During the past few years it has become an essential, and is used extensively in the rubber industry. Pure rubber is sensitive to heat and cold, but a vulcanized mixture of gilsonite and rubber has different physical and chemical properties, and will resist oxidation and changes in temperature.[12] This fact makes gilsonite a valuable constituent in rubber compounding. Gilsonite is used in the manufacture of prepared roofing and flooring materials, and in paving cements. When mixed with other hydrocarbons, gilsonite makes an ideal insulating material.

Mixed with fatty acid pitches it becomes a valuable paint for wood, iron, steel, leather, rubber, cork, concrete, and tin; when the solvent evaporates it leaves a highly luminous, black veneer coating, which is unchanged by acids, alkalies, water, or common gases. It is elastic, unaffected by moderate heat and is a good electrical insulator.

In 1918, 31,072 tons of gilsonite, valued at $663,257, were shipped by five producers in the Uinta Basin. So far as is known, no gilsonite was shipped from the Colorado vein.

[12]Ladoo, Raymond B., The natural hydrocarbons: Reports of Investigations, U. S. Bureau of Mines, May, 1920.

Henderson[13] reports the receiving of specimens of gilsonite, collected on Piceance Creek, southwest of Meeker. It is reported to occur in that area in considerable quantities.

Gilsonite, or some related hydrocarbon, probably ozokerite, occurs in the Dakota sandstones of the Rabbit Ears region. Grout[14] in describing the occurrence says:

"This is probably responsible for the mistaken idea of the settlers that several black shale banks are gilsonite. The most notable occurrence is about five miles north of Rabbit Ears, where a layer of the Dakota sandstone is sufficiently charged with hydrocarbons to give it a black or dark-brown color."

The chief use of grahamite is in the manufacture of prepared roofing, due, it is claimed, to the fact that mastic made from it is more resistant to grease and oil than that made from other ordinary hydrocarbons. It has a higher fusion point than gilsonite and so is usually softened with a heavy asphaltic flux. The resulting product becomes more rubbery and elastic, and is less susceptible to heat.

Grahamite is used as a substitute in the rubber industry, as a filler in brick and artificial stone blocks, in the manufacture of varnishes, in the manufacture of electrical wire insulation, and in molded insulation.

Many localities report the presence of bitumens, asphaltic sands, tar sands, bituminous shales, bituminous sandstones, and minor gilsonitic veins. All these deposits have been noted on the map; but owing to the lack of definite information regarding them they have been classed as natural hydrocarbons.

Deposits of native substances of variable color, hardness, and volatility composed of hydrocarbons substantially free from oxygenated bodies are called bitumens. These bitumens are sometimes associated with mineral matter, but regardless of associations, they are usually fusible and largely soluble in carbon disulphide.

A deposit of asphaltite is located on the east side of Sherman Creek in Sec. 24, T. 4N, R. 77W, near the northern edge of Middle Park. The deposit can be reached by following the road up Willow Creek from Granby station on the "Moffat" road.

The veins occur as fissure fillings in the clays, sandstones, and conglomerates of the Middle Park formation, a formation classed

[13]Henderson, Junius, Scientific expedition into Northwestern Colorado in 1909. Univ. of Colo. Studies, vol. 7, pp. 111-112.

[14]Grout, F. F., Worcester, P. G., Henderson, Junius, Reconnaissance of the geology of the Rabbit Ears region, Colorado: Colo. Geol. Survey Bull. 5, pt. I, p. 57, 1913.

as post-Laramie, but probably the equivalent of the Denver formation on the east side of the range.[15] This deposit is comparatively isolated, as the closest asphaltite is found near the Colorado-Utah line about 150 miles distant.

The fissures in this deposit were evidently filled, after opening, with material derived from adjacent strata, which are known to contain bitumens. The vein is traceable on the surface for 3,000 feet, and is very irregular, varying from a few inches to 6 feet in width. Considerable work has been done on the deposit, and the product has been hauled to Granby, from which point it was shipped to Denver and eastern markets. So far as can be ascertained, the deposit is not being worked at present.

OIL AND GAS[16]

JACKSON COUNTY

There is a large anticline east of Walden[17] in the area between the Canadian and Michigan rivers. A well is now being drilled on this structure, but accidents have delayed its earlier completion.

Another structure occurs along Pinkham Creek, near the mouth of King Canyon in the northeast corner of North Park.

MOFFAT COUNTY[18]

The principal anticlinal fold of this area appears to be a continuation of the Uinta Mountain axis. This fold is not of great magnitude, however, in the lower part of Axial Basin.

The Danforth Hills are composed of a system of folds by which the strata are bent into anticlines and synclines. The Thornburgh Mountain structure and the Sulphur Creek anticline are a part of this system.

Up to the present time no oil has been found in commercial quantity in this county.

RIO BLANCO COUNTY

The Rangely oil field is located in Raven Park, in the extreme northwestern corner of Rio Blanco County. The field occupies a basin which is a broadened portion of the lower White

[15] Willis, Bailey, Index to the stratigraphy of North America: U. S. Geol. Survey Prof. Paper, 71, p. 769, 1912.

[16] For location of anticlines, oil seeps, bitumen, oil sands, gas and oil springs, oil wells, and drill holes see accompanying map.

[17] Beekly, A. L., Geology and Coal Resources of North Park, Colorado: U. S. Geol. Survey Bull. 596, pp. 90-93, 1915.

[18] Gale, H. S., Coal fields of northwestern Colorado and Utah: U. S. Geol. Survey Bull. 415, pp. 98-102, 1910.

River valley. The valley itself has been eroded from the crest of the anticline.

Oil has been found in from 75 to 100 wells in the Mancos formation, but as these wells have not been systematically tested by pumping no conclusive data are at hand.

Practically the entire field is located within a government withdrawal which fact has retarded development work during the past few years. At present, however, substantial progress is being made and a paying field of small wells is confidently predicted.

Several structures have been located near Meeker, in the eastern part of the county, but no oil has been found up to the present time.

It is reported that oil in promising quantity has been found at a depth of less than 400 feet in a well about 15 miles north of Gunnison.

ROUTT COUNTY

According to Weston[19] a well was drilled several years prior to 1909 on a structure at Trull, on the Elk River, just above where it empties into the Yampa River.

A number of structures have been located in Routt County[20] and adjacent parts of Moffat County.

The Williams Park anticline lies southeast of Willow Creek in Moffat County, and in the Williams Park topographic basin two strong anticlines occur, the Sage Creek and the Fish Creek.

The Yampa or southern crest of the Tow Creek anticline has been tested by two wells, but the results were not favorable. The northern crest of this anticline is called the Chimney Creek dome, and the middle crest the Tow Creek.

It is reported that a heavy flow of gas was encountered in wells drilled on a structure in the Twentymile Park district, southwest of Steamboat Springs.

OIL SHALE

Immense volumes of oil shales occur in the Green River formation of western Colorado, eastern Utah, and southern Wyoming. In Colorado these areas are confined mainly to Moffat, Rio Blanco, Garfield, and Mesa counties. A small area of shale occurs in the extreme northern part of Delta County.

[19]Weston, W., The hydrocarbons of the Moffat Road, p. 24, 1909.
[20]Crawford, R. D., Some anticlines of Routt County, Colorado: Colo. Geol. Survey Bull. 23, 1920.

The total area of oil shale in Colorado is about 2,000 square miles, and may be divided into several well defined districts.

The first and largest area lies in Rio Blanco and Garfield counties, between the Grand River on the south, and the White River on the north. Government and Flag creeks mark the eastern boundary, while one branch extends along the line between Garfield and Rio Blanco counties almost to the Colorado-Utah line.

A second area lies in Moffat County, between Little Snake River and Vermilion Creek, and north of the Yampa River. This is a southern extension of the Wyoming deposits. The shales of this area are poorer than those in Rio Blanco and Garfield counties.

A small strip of oil shales extends along the Colorado-Utah line in the extreme western part of Rio Blanco County. This is the eastern edge of large deposits occurring in eastern Utah.

Small areas occur south of the Denver and Rio Grande Railroad, on Battlement Mesa, in Garfield and Mesa counties, and on Grand Mesa in Mesa and Delta counties.

The Green River formation, which contains the oil shales, is of Tertiary age. Below it lies the Wasatch, (Tertiary), and Mesaverde, (Cretaceous), formations. The Mesaverde is the principal coal-bearing formation of Northwestern Colorado.

The Green River formation is composed of a series of shales, sandstones, and calcareous oölites, with occasional beds of limestone, and conglomerate. The oil shales occur in the middle member of the formation, the top and bottom parts being barren. Where the upper member is eroded away oil shale may be exposed at the surface.

The oil shale strata vary considerably in thickness from place to place. In Colorado they are most extensively developed in Garfield and Rio Blanco counties where, in places, they attain an aggregate thickness exceeding 100 feet.

The shales range in color from black through blue and brown to gray or even yellow. They differ in character from massive to papery, limy, sandy, asphaltic, and waxy. The greater part of the Colorado shales are dark and massive.

The shale is an "oil shale" in name only, because it contains little or no free oil. The shale does, however, contain large quantities of organic remains, chiefly of vegetable origin.

Winchester[21] reports the finding of beautifully preserved beetles, flies, mosquitoes, bees, leaves of all kinds, fish skeletons,

[21]Winchester, D. E., Oil Shales: Journal of the Franklin Institute, vol. 187, pp. 689-704, 1919.

and even bird bones in the Green River series. Richer oil shales, he found, contain an abundance of vegetable material such as fragments of ferns, algae and fungi, bacteria, and pollen.

In addition to the plant and animal remains there are numerous small particles of bitumen.

By a process of destructive distillation these organic remains and the bitumen are converted into crude shale oil. This crude oil is in turn broken up by refining methods into gasoline, kerosene, lubricating oils, and paraffine.

A considerable amount of ammonium sulphate can be saved in the retorting of the shales. This is a very valuable and much desired fertilizer.

In discussing the by-products of oil shales, R. D. George[22] makes the following statement:

> "Analysis of several samples of spent shale showed an average potash content of eighteen pounds per ton of spent shale. This is water soluble and could be leached out at little cost."
>
> "The tars, still carbon, or coke and the heavy residual oils will be utilized about the plants or converted into marketable products."

Dean B. Winchester of the United States Geological Survey, has estimated that in Colorado alone there is sufficient shale, in beds that are three feet or more thick, to yield 20,000,000,000 barrels of crude oil, and that in addition, with but little more cost, there might be produced about 300,000,000 tons of ammonium sulphate.[23]

Although much of the oil shale region in western Colorado is remote from railroad transportation and not easily accessible, a large part is adjacent to transcontinental railroads. Branches can easily be built into many areas which are now without rail transportation.

PRECIOUS STONES

A large amount of chalcedony of gem variety is found throughout the northwestern part of the state. Agate is also found in some localities.

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[22]George, R. D., Oil Shale Problems: Railroad Red Book, vol. 37, No. 7, pp. 651, July, 1920. (Published by the Denver and Rio Grande Railway, Denver.)

[23]Winchester, D. B., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, p. 140, 1917.

SCORIA

Near Volcano, in Routt County, large quantities of scoria occur. This material has been used quite extensively in the ballasting of the tracks of the Moffat road through Routt and Moffat counties.

SILVER[24]

SUMMIT COUNTY

From the standpoint of value silver is the most important metal in the ores of the Tenmile mining district (Kokomo and Robinson) and in the Peru district, 8 miles east of Dillon.

URANIUM

MOFFAT COUNTY

Gale[25] reports the presence of a deposit of carnotite at the southern foot of Blue Mountain (called Yampa Plateau on the early maps of the region), about 18 miles east from the Colorado-Utah boundary. The deposit lies along the summit and flanks of the highest hogback, about 2 miles west of Skull Creek, which is the main east fork of the Red Wash.

The carnotite in this locality occurs in thick beds of white sandstone which show a large amount of cross bedding. The strata are undoubtedly Jurassic in age, as are those in which the carnotite occurs in southwestern Colorado.

RIO BLANCO COUNTY

Carnotite has been found about 14 miles by wagon road northeast of Meeker, on Coal Creek, which is one and one-half miles southeast of the locality known as "The Transfer," on Coal Creek.

In this region the carnotite is found at the summit of the hogback formed by the lowest of the most massive sandstones. The sedimentary rocks of the area are much more steeply tilted than those in southwestern Colorado.

VOLCANIC ASH

GRAND COUNTY

A small deposit of volcanic ash occurs, on the south side of the Grand River, about one and one-half miles southeast of Krem-

[24]See Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician, U. S. Geol. Survey.

[25]Gale, Hoyt S., Carnotite and associated minerals in Western Routt County, Colorado: U. S. Geol. Survey Bull. 340, pp. 257-262, 1908.

mling. The ash is very uniform in size and is composed of thin white flakes with very angular edges.

The material of the deposit is generally white, although in places it has been stained a light brown by percolating solutions containing iron.

A gray appearing volcanic ash is now being shipped from a deposit near Troublesome. This material is shipped to Denver where it is used in the manufacture of hand soaps and scouring powders.

MOFFAT COUNTY

Volcanic ash has been reported as occurring in the extreme northwestern part of Moffat County,[26] near the Colorado-Utah line.

[26]Montgomery, Henry, Volcanic dust in Utah and Colorado: Science, new series, vol. I, pp. 656-657, 1895.

CHAPTER II

MINERAL DEPOSITS OF WESTERN COLORADO

BARITE

GUNNISON COUNTY

Barite occurs as a gangue mineral in the ores of several mines in Gunnison County. Particularly fine specimens have been found at various times, but deposits of commercial importance are not yet known.

MESA COUNTY

It is reported that low-grade barite has been found in the vicinity of Grand Junction, but no further information has been obtained concerning the deposit.

OURAY COUNTY

In the Ouray district, deposits of baritic siliceous ores are found as flat masses associated with vertical fissures, and as a gangue mineral in lateral enrichments of silver veins in the Newsboy, the Pony Express, and the Mineral Farm mines.[27]

In the Mineral Farm mine the ores consist of fine-grained silica heavily charged with crystalline barite, and containing argentiferous gray copper, galena, and chalcopyrite. The barite could easily be saved in the milling of the ore.

PITKIN COUNTY

Barite is a common gangue mineral in the ores of the Smuggler and Mollie Gibson mines at Aspen. In the Smuggler mine[28] rich silver ore is enclosed in flesh-colored or gray barite. In the Mollie Gibson mine most of the ores carry barite as a gangue min-

[27]Cross, Whitman, Howe, Ernest, Irving, J. D., Geology of the Ouray quadrangle, Colorado: U. S. Geol. Survey Geol. Atlas, Ouray folio (No. 153), p. 18, 1907.

[28]Spurr, J. E., Geology of the Aspen Mining district: U. S. Geol. Survey Mon. 31, pp. 184-189, 1898.

eral. Other mines of the district contain barite as a common gangue mineral.

No attempt has been made to separate or save the barite of the district. The high freight rates to outside points of consumption naturally prevent the mining and shipment of the mineral.

SAN MIGUEL COUNTY

In San Miguel County, barite occurs 2 miles north of Placerville in veins from 2 to 7 feet wide.[29]

Barite is a common gangue mineral in the ores of many of the metal mining camps of the western and southwestern parts of the state. In prospecting for the metals, barite is often encountered, but as it has a low value compared to the metals very little attention is paid to saving it. Up to the present time there has been no commercial production in western or southwestern Colorado.

BUILDING STONE

GUNNISON COUNTY

Granite.—The Aberdeen granite quarry is located in Gunnison County, on South Beaver Creek, about 4 miles from the point where that stream empties into the Gunnison. It is 11 miles from the town of Gunnison. The quarry site includes about 120 acres of land.

The quarry was opened in 1889 and has produced a total of 290,000 cubic feet of very high grade building stone, most of which was used in the State Capitol. The area affords an inexhaustible supply of the highest grade of building granite.

GUNNISON COUNTY

Lava.—A good grade of lava rock has been quarried near Gunnison. The deposits are large, the rock is easily worked and is suitable for sills, belt courses, and quoins.

GUNNISON COUNTY

Marble.—Large deposits of extremely good marble, of medium fine texture, and of several colors are found on Yule Creek and in the adjacent areas. This marble has been used extensively for building purposes in Denver and eastern localities.

[29]Schrader, F. C., Stone, R. W., Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 82, 1916.

PITKIN COUNTY

Granite.—Some granite has been produced from a quarry 10 miles southeast of Aspen. There is much excellent stone available.

PITKIN COUNTY

Marble.—Some marble has been found in Pitkin County, near Aspen. It is of a beautiful gray color, varies in texture from coarse to fine and even. It is easily worked and could be used freely as a substitute for the Bedford (Indiana) stone which finds a ready market in Colorado.

GUNNISON COUNTY

Slate.—Slate is reported as being quarried in the same area of metamorphism as that in which large deposits of marble are found on Yule Creek.

Sandstone.—The standstones of the McElmo, Dakota, and White Cliff formations are especially well suited for building purposes. These formations occupy large areas in western Colorado, and furnish good, easily quarried building material. In certain localities a light red sandstone from the Hermosa formation is utilized for building. Dark red sandstone from the Cutler, and gray sandstone from the La Plata formation are used in other localities. The quantity of these is very large.

DELTA COUNTY

Sandstone.—Quarries are located near Austin and at Delta. The product has been used locally in building operations.

EAGLE COUNTY

Considerable red sandstone has been shipped from quarries at Peachblow, east of Basalt, on the Colorado Midland Railroad. The sandstone is rather soft, and very little has been used during the past few years.

MESA COUNTY

Pink sandstone has been quarried from the La Plata formation southwest of Fruita. The rock has been used locally for building purposes.

MONTROSE COUNTY

Sandstone has been quarried at Montrose and Olathe. It is reported that the entire output was used locally.

OURAY COUNTY

Light red sandstone from the Hermosa formation, dark red sandstone from the Cutler formation, and gray sandstone from the La Plata formation are used locally in Ouray County.

CLAYS

WESTERN COLORADO

The shales of the Mancos formation are abundant in the western part of the state. These shales are well suited for the manufacture of ordinary brick, and are being utilized at a number of places. The shales of certain other strata in the Mancos formation are suitable for the manufacture of pressed brick, soft mud bricks, and earthenware. Clay from a bed near the top of the Mancos formation appears suitable for the manufacture of semi-refractory brick.

The Dakota and Mesaverde formations contain numerous lenticular beds of fire clay. The fire clays of the Dakota formation are generally found within the sandstone, and are indicated by a black clay line which is readily recognizable. The fire clays of the Mesaverde formation are found underneath the coal seams, or are mined with the coal. These clays are impure, and not as good as those found in the Dakota formation.

The Lewis formation should furnish shales suitable for the manufacture of ordinary brick.

River terrace clays are worked at Glenwood Springs, Aspen, Grand Junction, and numerous other localities in western Colorado. Wherever these are being worked, the less sandy clays are more likely to be found the greatest distance back from the river.

In Garfield County, plastic clay from the Dakota sandstone near Glenwood Springs, has been mixed with crushed quartz, and made into bricks for coke ovens at Cardiff.[30]

COAL

BOOK CLIFFS COAL FIELD

The Book Cliffs form the southern margin of the Book or Tavaputs Plateau, and extend from Grand River, Colorado, to Helper, Utah.

The Book Cliffs field, in Colorado, covers approximately 360 square miles, most of which is easily accessible.

[30]Schrader, Frank C., Stone, Ralph W., and Sanford, S., Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 84, 1917.

Coal of commercial importance occurs in the lower part of the sandstone and shale formation which is known as the Mesaverde. The coal is found at various intervals from 35 to 700 feet above the shale that underlies the lowland.

It occurs at different horizons, and no bed has been traced continuously for more than a few miles. In some places only one bed of coal is present while at others there are several.

The coals of the Book Cliffs may be classed as medium-grade bituminous, and they compare favorably with the product of the Rocky Mountain region and the Mississippi Valley.

The total production from 15 mines operated in Mesa County during 1918 was 220,369 tons.

GRAND MESA COAL FIELD

The Grand Mesa coal field extends from Cameo, on the Grand River, south and then east as far as the Somerset and Bardine districts in Gunnison County. The district includes approximately 550 square miles of coal lands.

The coals of the field vary from the low-grade bituminous coals, found in the western part of the field, to the semi-anthracite of the east end of the field.

No close estimate can be made of the amount of coal in this field, until a more extensive study has been made of the area. The average thickness of the coal varies from 11 feet in the Palisades district to 65 feet in the Somerset district.

According to Lee,[31] after deducting 25 per cent for waste in mining, there would remain 14,881,703,160 short tons of available coal in this district, mainly on Government land.

During 1918, 13 mines in Delta County produced a total output of 94,870 tons of coal. During the same period two mines in Montrose County produced 1,020 tons of coal.

COPPER[32]

MESA COUNTY

The Unaweep Copper district is located 25 miles southwest of Grand Junction, and about 12 to 13 miles west of Whitewater, on the Montrose branch of the Denver & Rio Grande Railroad. This district has possibilities which have not been developed up to the present time.

[31] Lee, W. T., The Grand Mesa Coal field, Colorado: U. S. Geol. Survey Bull. 341, pp. 316-334, 1909.

[32] Also see Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician U. S. Geol. Survey.

MONTROSE COUNTY

Copper is found in the ores of the La Sal and Paradox mining districts, located 76 miles west of Placerville, in the extreme western part of Montrose County.

OURAY COUNTY

In the Red Mountain district, between Silverton and Ouray, copper predominates over silver, gold, and lead. The production of Ouray County in 1919 was $7,696. The total production from 1878 to 1917 was $3,207,240.

FLUORSPAR

GUNNISON COUNTY

Fluorspar is found as a gangue mineral in the lead ores of the Lead King mine at Crystal. Some colorless material suitable for optical purposes has been found, but its occurrence is not common.

HINSDALE COUNTY

The ores of the Hidden Treasure mine contain occasional crystals of fluorspar among the gangue minerals. Although a small amount of flourspar is common in the ores of the district, the quantity is not sufficient to be of commercial importance.[33]

MONTROSE COUNTY

A small vein of flourspar has been prospected about 14 miles northeast of Montrose. This deposit is located on the south side of the Gunnison Canyon, on Vernal Mesa. The samples show a calcium fluoride content of 33 per cent, whereas, 80 per cent or greater is the desired content.

OURAY COUNTY

Fluorspar occurs as a gangue mineral in many of the veins of the district. In the Camp Bird, Micky Breen, and Grizzly Bear mines green fluorspar in pieces up to 4 inches in diameter is found associated with quartz, rhodochrosite, galena, pyrite, and sphalerite.

A vein of fluorspar from 3 to 5 feet in width was found in the Barstow mine during the summer of 1917. About 1700 tons (averaging above 90 per cent calcium fluoride) was shipped from

[33]Irving, John D., and Bancroft, Howland, Geology and ore deposits near Lake City, Colorado: U. S. Geol. Survey Bull. 478, p. 46, 1911.

the property during 1917-1918. Some of the fluorspar appears to be suitable for optical purposes, as it is nearly colorless or light green, and seems to be only slightly fractured.

The vein was first cut at a depth of 1050 feet. It was then opened in a level 140 feet above that point and 600 feet distant horizontally. Additional work has proven that the vein continues in the opposite direction, and that the ore bodies are of far greater size than was at first supposed.

The fluorspar is of very high grade and can be sorted and washed to meet any demands. Under normal conditions, the high freight rates and cost of haulage to the railroad will not permit its competition with eastern fluorspar.

It may pay, however, to mine and ship fluorspar from this deposit when there is a demand for high grade fluorspar for use in the chemical industry.

The Torpedo Eclipse and Ruby Trust mines, at Sneffels, contain large bodies of good grade fluorspar, and discoveries have also been reported in other metal mines in the county.[34]

SAN MIGUEL COUNTY

Flourspar is found as a gangue mineral in the ores of the Telluride district. In the Tomboy mine, many small crystals of colorless to greenish flourspar are found.[35]

GOLD[36]

EAGLE COUNTY

Gold is the predominant metal in the ores of the Fulford district, 18 miles southeast of Eagle, and in the Holy Cross district, 18 miles southwest of Red Cliff. During 1919, the value of the gold produced in Eagle County was $19,059. The total production of the county from 1879 to 1915 was $2,145,464.

GUNNISON COUNTY

Although more silver than gold has been produced in Gunnison County, gold is the predominant metal in the ores of several districts. Gold predominates in the ores of the Box Canyon district, 11 miles south of Pitkin; in the ores of the Cebolla district, 18 miles south of Iola; in the Cochetopa district, 5 miles south

[34]Carroll, Fred., Colorado State Bur. Mines Fifteenth Bienn. Rept. for 1917-1918, p. 131, 1919.

[35]Cross, Whitman, and Purington, C. W., U. S. Geol. Survey Geol. Atlas, Telluride folio (No. 57), p. 16, 1899.

[36]See Hill, J. M., The mining deposits of the western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician U. S. Geol. Survey.

of Parlin; in the Gold Brick district, 3 miles north of Ohio City; and in the Tincup district, 37 miles southwest of Buena Vista.

From 1873 to 1917 Gunnison County produced $2,112,520 in gold.

OURAY COUNTY

In Ouray County the following districts show a predominance of gold over other metals:

Imogene Basin (Camp Bird), 8 miles southwest of Ouray; the Sneffels district, 8 miles west of Ouray; and the Uncompahgre district around Ouray.

Between 1878 and 1917, $34,675,607 in gold was produced from Ouray County.

SAN MIGUEL COUNTY

Gold predominates in the ores of the Telluride district, the Iron Spring district at Ophir, and the Lower San Miguel district around Placerville, Sawpit, and Vanadium (Newmire).

The production of gold in San Miguel County in 1919 was valued at $2,124,837. The total production from 1875 to 1917 amounted to $49,956,607.

GRAPHITE

GUNNISON COUNTY[37]

There are three parallel nearly vertical "veins" about 50 feet apart and conforming to the bedding of the enclosing sedimentary rocks. The largest vein has a width of 4 to 6 feet. The graphite is the result of the extreme metamorphism of coal seams of Cretaceous age.

The deposits are near the head of Cement Creek, about 10 miles from the railroad. The development consists of a number of open cuts near the summit of Italian Mountains.

The quality of the graphite varies with the intensity of the metamorphism, but there appears to be an immense tonnage of good material.

A large vein of amorphous graphite is traceable for more than 10 miles between White Pine and the Tin Cup district. The vein varies from a few inches to several feet in width, but shows a considerable amount of marketable graphite.

Some development work has been done on the vein, and in the Quartz Creek district several mines have shipped ore. Prior

[37]U. S. Geol. Survey Mineral Resources, pt. II, p. 1067, 1912.

to May 3, 1918, the property operated by Woodruff and Woodruff shipped over 1,000 tons of graphite,[38] while several other properties shipped smaller amounts.

After the signing of the armistice there was a sharp decline in the price of graphite. This resulted in a suspension of operations in the mines on Quartz Creek, as the cost of mining and hauling the ore 5 miles to Quartz station and the freights beyond this point were excessive.

During 1919 only 2 cars of graphite were shipped from the Quartz Creek district.

GRINDSTONES

GUNNISON COUNTY

A sandstone stratum, suitable for the making of grindstone, occurs near Gunnison. The deposit lies just outside the city limits, on the bank of the Gunnison River, and in close proximity to the railroad. Water for power purposes and for quarry use is readily available.

The Dakota formation outcrops at this point and is exposed for about one-half mile. It consists of about 21 feet of workable material.[39] The top 8 feet of sandstone is suitable for grindstone purposes, the next 8 feet for fine grindstones and oil stones, and the next 5 feet for very fine oil stones and razor hones. It is claimed that when pulverized the finer-grained sandstone makes a fine polish for gold and silver ware.

The sandstone appears to be well adapted for abrasive purposes, as it is fine grained, even textured, and has good adhesive properties.

GYPSUM[40]

Gypsum is widely distributed throughout the western slope of Colorado, though commercial deposits appear to be confined to but few geological formations. In quantity, the supply is almost unlimited and unless very important new uses are found either for the raw mineral or the manufactured products there is enough to meet the demands for centuries. By far the larger part of the gypsum is of the granular rock variety, occurring interstratified with other sedimentary rocks. Here and there through the weath-

[38] Carrol, Fred., Colorado State Bur. Mines Fifteenth Bienn. Rept. for 1917-1918, p. 134, 1919.
[39] Mining Science, Gunnison, Colorado, Grindstone Quarries: vol. 62, p. 625, 1910.
[40] Excerpts from paper by R. D. George on "Gypsum deposits of Colorado."

ering of the rock gypsum considerable accumulations of gypsite have been formed.

Of the vast volume of gypsum in the state a very large proportion is of excellent quality, and analyses show as high as 99 per cent of hydrous calcium sulphate. In places the deposits must be classed as gypsiferous shales and are commercially useless.

On the western slope the Carboniferous was by far the most important period of gypsum deposition, and probably 90 per cent of the gypsum occurs in strata of Pennsylvanian and Permo-Pennsylvanian age.

RIO BLANCO, GARFIELD, EAGLE AND PITKIN COUNTIES

Along the valleys of the White, Grand, and Eagle rivers, and such tributaries as the Roaring Fork, Frying Pan, Brush, Gypsum, Cottonwood, and others, large areas of the Upper Carboniferous formations of the Hayden geologists are exposed. In many places along these streams the outcropping edges of the strata show large deposits of gypsum and gypsiferous shale varying in color from pure white to pink, gray, and almost black. The predominant color of the gypsiferous shale is gray, and that of the gypsum beds is an ashy gray which is very easily recognized.

In some places the weathering of the gypsum has covered wide slopes with a soft flour-like gypsite more or less mingled with alluvial materials from the higher strata. The general geological relationships are such as to suggest an equivalence of age with the deposits along the eastern foothills of the range, though in places gypsum is possibly in strata corresponding to the Hermosa of the San Juan country, and is thus of Pennsylvanian age.

At Ruedi on Frying Pan Creek in Pitkin County a plaster mill was in operation for a few years, but it is now closed down. A few carloads of gypsum have been shipped from Gypsum station to Portland, Colorado, for use in the manufacture of cement. The supply is almost unlimited.

Northward from Gypsum station, gypsum[41] occurs in large masses, outcropping in hillsides, in the gullies and on mountain tops for about 4 miles back from the Eagle River. The strip of land 3 or 4 miles wide, including the divide between the Eagle River and Grand River basins, appears to be composed of a limy shale and thin limestone carrying little or no gypsum. On the

[41]Burchard, E. F., Gypsum deposits in Eagle County, Colorado: U. S. Geol. Survey Bull. 470, pp. 360-361, 1911.

slope towards Grand River gypsum is again present in abundance, occurring in enormous masses in the gulches and on the hillsides.

None of the deposits on the slope toward the Grand River can become commercially important until a railroad is built down the Grand River connecting the Denver and Salt Lake Railroad at Orestod, with the Denver and Rio Grande Railway at Dotsero.

The gypsum also appears on both sides of Spruce Creek and on both sides of the Roaring Fork. In all these areas the strata and gypsum deposits are very similar to those along the Eagle River.

Gypsum[42] occurs in strata and lenses of various dimensions interbedded with shale, but is not confined to definite horizons. The lenses range from a few yards to miles in length, and in thickness from a few feet up to 200 feet or more. The lenses generally contain shale bands or beds mixed with gypsum and consequently contain more or less impurities. Two and one-half miles east of Gypsum, in a stratigraphic section 140 feet thick, the gypsum measures 90 feet. Here selenite and anhydrite are plentiful.

Along the open valley of the Eagle River, between the Canyon and a point five or six miles above the Grand, the bordering hills are formed of gypsiferous shale and gypsum, which break down into a soft powdery gray to white mass of impure gypsite and alluvium. In the lower canyon of Eagle River gypsum beds dip from the river in both directions, and the peculiar erosion of these hills has developed a topography resembling that of the bad lands.

A section measured on the Eagle River consists of about 1,500 feet of shales, sandstones and limestones, often showing transitions from one type to another.[43]

Of the total thickness probably one half is gypsum bearing. From fossil evidence Lesquereux[44] determined the age to be Permian. Recent work supports this finding.

UNCOMPAHGRE REGION

Siebenthal[45] describes the occurrence of gypsum along the Grand Canyon of Gunnison River in Delta and Montrose counties. The gypsum measures outcrop uninterruptedly for 20 miles, from

[42]Burchard, E. F., Gypsum deposits in Eagle County, Colorado. U. S. Geol. Survey Bull. 470, p. 357, 1911.

[43]Burchard, E. F., Gypsum deposits in Eagle County, Colorado. U. S. Geol. Survey Bull. 470, pp. 354-364, 1911.

[44]Lesquereux, Leo., Permo-Carboniferous strata of Eagle River: U. S. Geol. Survey of the Territories by F. V. Hayden, vol. 8, pp. 118-119, 1874.

[45]Siebenthal, C. E., Gypsum of the Uncompahgre region, Colorado: U. S. Geol. Survey Bull. 285, pp. 401-403, 1905.

a point below the mouth of Smiths Fork southward to Red Rock Canyon. These measures average 110 feet in thickness and reach a maximum of 150 feet.

The gypsum occurs in a series of shales and sandstones of undetermined age, but separated from the so-called Dakota by 400 feet of variegated but predominantly reddish shales, with interbedded red and buff sandstones. The description of the sandstone, resting on the pre-Cambrian schists suggests the "Crinkled Sandstone" of the Lykins east of the range.

Efforts have been made to develop the gypsum deposits northeast of Montrose, but so far all the enterprises have failed, due to the lack of capital, and to the cost of transporting the product to market. In this vicinity there appear to be four distinct strata, two are six feet, one ten feet, and one sixteen feet in thickness.

GUNNISON COUNTY

Howell[46] mentions the occurrence of gypsum on the east side of the river near Gunnison.

IRON

GUNNISON COUNTY

Numerous deposits of iron ore have been found in Gunnison County. The greatest of these deposits, and perhaps the largest in the state, is located about two and one-half miles southeast of Powderhorn, on the north side of Cebolla Creek. This deposit contains a large tonnage of magnetite and limonite. Very little development work has been done because of the lack of transportation facilities.

Several thousand tons of iron ore were shipped from the Iron King mine at White Pine, and used as a flux in the old lead smelter at Gunnison.

Large deposits of iron ore are found on Taylor River, but have never been developed, because of the lack of transportation facilities in that district.

Bog iron is found in various localities in the Crested Butte district. The largest deposit occurs in Redwell basin, on the north side of Scarp ridge. Another deposit of almost equal size is found in the valley of Coal Creek, nearly opposite the deposit in Redwell basin.

[46]Howell, E. E., Geology of a portion of Colorado explored and surveyed in 1873; Wheeler Survey Rept., vol. 3, p. 264, 1875.

OURAY COUNTY

Magnetite-pyrite ore occurs in the Bright Diamond and Iron Clad mines, high up on the sides of the Uncompahgre Canyon, below Ouray.

PITKIN COUNTY

A deposit of iron ore is found high up the side of one of the mountains forming the base of Hayden Peak. This deposit is practically inaccessible at present.

LEAD[47]

GUNNISON COUNTY

Considerable lead is mined in the Tomichi (Whitepine) and Elk Mountain mining districts in Gunnison County. The Tomichi district is located 12 miles northeast of Sargents, on the Denver & Rio Grande Railroad. The Elk Mountain district is located near Crested Butte.

Gunnison County produced lead to the value of $154,620 during 1919, and between 1873 and 1917 the value of the lead produced was $1,723,272.

HINSDALE COUNTY

Lead is the principal metal produced in the Galena mining district, 5 miles west of Lake City.

PITKIN COUNTY

Lead is the principal metal in the ores of the Ashcroft district, 12 miles south of Aspen, and in the Aspen district itself.

During the past few years the value of the lead produced has been greater than that of the silver. During 1919 the high prices paid for silver reversed this condition.

The production of lead in 1919 was valued at $301,141. The total production from 1880 to 1917 was valued at $23,802,993.

A fine grained blue gray limestone is found in the vicinity of Aspen. This rock is particularly well suited for building purposes, as it has a good color, cuts well, and is quite resistant to weathering. It is only slightly harder than the well known Bedford limestone, but should cut and market equally well.

LIMESTONE

Nearly all the Carboniferous formations of western Colorado contain strata of commercial limestone which could be used for

[47]See Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician, U. S. Geol. Survey.

fertilizers, or in the manufacture of lime and Portland cement. Shale necessary for cement manufacture is readily available throughout many areas in western Colorado, and in most cases is adjacent to the limestone deposits.

The limestones show a low magnesium content, and would make an excellent lime.

DELTA COUNTY

Limestone has been quarried near Dominguez, in Delta County. The entire product has been used locally for building purposes.

GUNNISON COUNTY

Considerable quantities of limestone are found in the vicinity of Gunnison. Lime has been burned in kilns on Cement Creek. Limestone was used as a flux during the earlier smelting activity in Gunnison County.

OURAY COUNTY

Almost inexhaustible quantities of limestone may be had from the Ouray and Hermosa formations in the Ouray district. The limestone is suitable for nearly all purposes, such as lime and cement manuacture, flux for smelting, and stone for building purposes.

PITKIN COUNTY

Lime kilns were operated at Thomasville and Meridith for some years. The quarries at Thomasville were at one time operated on a fairly large scale, and a good grade of lime was produced.

MANGANESE[48]

EAGLE COUNTY

Two immense lenses of low-grade manganiferous iron ore have been developed at Red Cliff, by the Empire Zinc Company.

These great lenses occur parallel to the bedding of the Carboniferous limestone of the district. They crop out on the sides of the canyon wall 400 or 500 feet above the river, two or three miles below the town of Red Cliff. The two lenses appear to occupy the same stratigraphic position, but are found nearly one-half mile apart.

[48]For a full discussion see Muilenburg, G. A., Colo. Geol. Survey Bull. 15, 1919.

In the western one of these great lenses, manganese oxides form the greater part of an ore body 3,000 feet long by 1,000 feet wide. The thickness is variable, but will probably average 50 feet.

It has been estimated that this deposit alone is capable of producing 500,000 tons of marketable manganiferous iron ore.[49]

The eastern deposit is somewhat smaller than the west, but it has been estimated that this deposit is capable of producing between 250,000 and 500,000 tons of manganiferous iron ore. It is said that 200,000 tons have already been produced from this deposit. This would make a total of from 750,000 to 1,000,000 tons of marketable ore in the two great lenses.

Four miles south of Sapinero, manganese occurs in pockets having the shape of large kidneys or botryoidal masses. This occurrence is in many ways similar to that in Steuben Valley.

Small deposits of manganese have been found on the ridge between Little Cimarron and Big Blue creeks, about 12 miles from Cimarron, and in the extreme southwestern part of Gunnison County and adjoining parts of Hinsdale County.

HINSDALE COUNTY

A small amount of development work has been done on a deposit of manganese, located near Burrows Park, from 12 to 14 miles above Lake City on the Lake Fork of the Gunnison River. The vein material is practically all rhodochrosite which has altered to pyrolusite in the oxidized zone.

Small deposits of manganese have been reported as occurring on Henson Creek, 10 miles from Lake City, and on Alpine Plateau, near the foot of Uncompahgre Peak.

OURAY COUNTY

A small amount of manganese ore was shipped to the smelter at Ouray from the Ackerson property, on the lower part of Hayden Mountain. This ore body was opened to obtain a flux for the smelter, but only a small tonnage was shipped before the smelter was closed.

The deposit occurs in the Carboniferous limestones just back of the Mineral Farm mine, and the ore is said to be very well suited for fluxing purposes as it contains a small amount of lime.

GUNNISON COUNTY

Large bodies of manganiferous iron ore have been found along Taylor River, northeast of Gunnison, in the vicinity of White Pine

[49]Umpleby, J. B., Manganiferous iron ore occurrences at Red Cliff, Colorado: Eng. and Min. Jour., vol. 104, pp. 1140-1141, Dec. 29, 1917.

and Tincup, and 2 miles southeast of Powderhorn postoffice, in the southwestern part of Gunnison County.

The ores in the Taylor River, White Pine and Tincup areas are mainly hematite and magnetite, with unaltered sulphides and silicate minerals. Analyses show the main ore body is mostly iron, in which the silica and phosphorous contents are low and the sulphur content is high.

In the Cebolla Valley district the manganese is associated with the deposits of siderite, hematite, and limonite ores. The manganese occurs in the form of pockets or lenticular beds. These lenses are from 1 to 4 feet thick and occur as replacements along the bedding and joint planes of the limestone.

The ore occurs in a series of hills north of Cebolla Creek, and the rocks appear to have a strike north and south, parallel to the creek.

Manganese, associated with limonite, is found irregularly distributed through metamorphic rocks and intrusive granites of the area 4 miles southeast of Powderhorn.

A small quantity of manganese ore has been found in Steuben Valley, a tributary of the Gunnison River. The ore is widely scattered and occurs in cavities in a breccia composed of angular and partly rounded fragments imbedded in a sandy matrix.

SAN MIGUEL COUNTY

A deposit of high grade manganese ore occurs near the top of the divide separting Gypsum Valley from Dry Creek Basin. This location is 45 miles southwest of Placerville, a station on the Denver and Rio Grande Railroad.

Development work on one of four claims has proven the existence of an ore body at least 1,200 feet long and 235 feet wide, with an average thickness of about 20 inches. It is said that 50,000 tons of marketable manganese can be mined from this claim alone, whereas, three other adjacent claims should furnish a considerable tonnage of good ore.

A small deposit of manganese has been located about five miles southeast of Naturita, near the top of the divide between the San Miguel River and Dry Creek Basin.

MARBLE

GUNNISON COUNTY

Burchard[50] describes the occurrence of marble on Yule Creek in Gunnison County as follows:

"The most extensively developed deposits of marble in Colorado are on Yule Creek, in northern Gunnison County. The deposits that are quarried here are high on the left bank of the creek and dip westward at an angle of about 52°. The marble bed is reported to be about 240 feet thick, and to contain four bands of chert, each 2 to 4 feet thick. The underlying rock is cherty blue dolomite, and overlying the marble is a sill of igneous rock which is, in turn, overlain by 500 to 800 feet of blue cherty limestone. The marble itself is for the most part white and of medium, fine grain, but there are bands of handsome green-stained material within the mass."

Loughlin[51] reports the presence of three varieties of marble in the district, the white, the "Colorado Cloud" with black veining, and the "golden vein" with yellow veining. Many other types of marble have been found in the Yule Creek district and adjacent areas.

A large amount of marble was shipped from the Yule district prior to the time operations were stopped. One of the finest buildings constructed of Colorado-Yule marble is the United States postoffice in Denver.

A black, white vein brecciated marble has been found in the Pitkin district. Several localities in the region of Gunnison report the occurrence of marble. A particularly fine piece of coarsely crystallized, banded marble was seen in Gunnison, and was reported to have been found southeast of the town.

MICA

MESA COUNTY

A deposit of mica is located in Ladder Canyon, Mesa County, about 8 miles south of Grand Junction. The mica streak ranges from 1 to 3 feet in thickness and is composed of nearly solid masses of muscovite crystals. The crystals are much ruled and broken, and nearly all have the "herring bone" structure. It is probable that the entire yield of mica from this deposit is suitable for grind-

[50]Burchard, E. F., U. S. Geol. Survey, Mineral Resources of the United States for 1912, pt. II, p. 810.

[51]Loughlin, G. F., U. S. Geol. Survey. Mineral resources of the United States for 1914, pt. II, p. 866.

ing purposes. As yet there has been found only a little mica that can be cut into sheets, but further development may open up more.

MONTROSE COUNTY

A considerable amount of mica occurs in the pegmatite vein on Vernal Mesa, north of Montrose. Nearly all the mica of the deposit has the "herring bone" structure and would, in all probability, have to be ground.

MINERAL COKE

GUNNISON COUNTY

Natural coke has been reported as occurring in the Anthracite-Crested Butte district.

MINERAL WATERS

Western Colorado is remarkable for the abundance and variety of her mineral waters. Many of the springs are in the midst of scenery of the greatest beauty and grandeur. In many places the climatic conditions are ideal for health and summer resorts. Many of the waters are of such composition and curative properties as to justify the expectation of a large sale if they were better known.

A report on the Mineral Springs of the State, by the Colorado Geological Survey, is now in press, and will be available in a short time. Only the briefest references to the mineral waters will be made in this bulletin.

Delta County—Sulphur Springs occur near Austin. An artesian well near the mouth of Black Canyon yields a very strong mineral water.

The Doughty springs near Hotchkiss are well known.

Eagle County—The Dotsero springs are among the largest in the State.

Garfield County—The Glenwood Springs are a large group of highly mineralized springs well provided with baths, plunges, pools and hotel accommodations.

At South Canon a short distance below Glenwood are several developed springs.

Near Cardiff is a sulphur spring.

Gunnison County—In the general vicinity of Crested Butte there are several springs. Two are about 8 miles northeast of the town, two others are on Cement Creek about 8 miles from Crested Butte, and another occurs between Irwin and the town.

Waunita Springs are well developed as a health and pleasure resort.

The Cebolla or Powderhorn Springs are also a notable group of developed springs.

Hinsdale County—A short distance east of Lake City in Sparlin Gulch; and in Slumgullion Gulch west of Lake San Cristobal are mineral springs.

Mesa County—Several springs are found in the valley of Plateau Creek south of DeBeque.

Montrose County—There are mineral springs near the junction of Cimarron Creek and the Gunnison; at Long Park and elsewhere. They are undeveloped.

Ouray County—Mineral springs occur near Ridgway; in Ironton Park, and at the town of Ouray. Only the last are developed.

Pitkin County—Near Thomasville there are two large sulphur springs beside the Midland railway.

At Avalanche in the valley of Crystal River there are several mineral springs, some of which are slightly improved.

There is also a mineral spring near Castle Peak at the head of Conundrum Creek.

San Miguel County—A developed spring at Placerville is known as "Warm Geyser Spring." There are others in the county.

MOLYBDENUM[52]

Commercial deposits of molybdenum, in Colorado, are confined to the igneous and metamorphic rock ages, or to contact deposits on the borders of igneous rock areas. Large areas in Colorado show conditions which are apparently favorable for the occurrence of molybdenum.

Molybdenum is very likely to be found near the borders of granite intrusions and in pegmatite dikes. Intrusions of acidic igneous rocks may contain some molybdenum, while basalts and other basic rocks are not likely to contain molybdenum, except where they come in contact with the more acidic intrusions.

GUNNISON COUNTY

Quartz and Tincup Mining Districts

Several veins which contain molybdenite have been located in the vicinity of Gold Hill, 9 or 10 miles north of Pitkin.

[52]For a full discussion see Worcester, P. G., Molybdenum deposits of Colorado: Colo. Geol. Survey Bull. 14, 1919.

Worcester[53] describes the occurrences in this district as follows:

"One large fissure vein, which has been traced more or less continuously for more than two miles, crosses Gold Hill in a northwesterly direction. Another vein is indicated by float in the timber south of Gold Hill and the creek. On top of Gold Hill there are still several outcrops which indicate that there are several veins only imperfectly exposed."

The molybdenite occurs as grains, flakes, crystals, or facings in quartz veins which cut through the quartz monzonite of the district. The molybdenite is usually associated with some pyrite and chalcopyrite. Copper is present in one of the veins to such an extent as to make the ore valueless for ordinary purposes. Tungsten (Hübnerite) is also present in one of the veins on the Ida May claim.

A deposit of molybdenite occurs near the outlet of Lamphere Lake, seven miles due north of Ohio City. The molybdenite is found in both large and small quartz veins cutting the granite of the district. Most of the molybdenite occurs as crystals, but some fine grained facings have been found.

Molybdenite has also been found on Cross Mountain, in Taylor Park, between Gunnison and Tincup, near the old town of Spencer, 15 miles south and west of Iola; on Paradise Pass, 12 miles northwest of Crested Butte, and on the southwest slope of Treasury Mountain.

HINSDALE COUNTY

An occurrence of molybdenite has been located 3 or 4 miles north of Lake City and about one mile west of the railroad.

The molybdenite occurs as small flakes in quartz veins. The quartz veins cut the fine grained rhyolite, which is the principal country rock of the area.

MESA COUNTY

What appears to be a very low grade molybdenum ore has been found in the Gavette claim, on the north side of Unaweep Canyon, about 29 miles from Whitewater.

A second occurrence is located about 2 miles northeast of the Gavette property. This occurrence is also on the north side of Unaweep Canyon.

[53]Worcester, P. G., Molybdenum deposits of Colorado: Colo. Geol. Survey Bull. 14, p. 59, 1919.

OURAY COUNTY

Molybdenite occurs in the Irene claim, about one-half mile north of Ironton, 400 feet above and parallel to the creek.

The molybdenite occurs in a quartz vein associated with pyrite, traces of gold and silver, and 7 per cent of lead. The molybdenite is fine grained and intimately mixed with the quartz of the vein.

A second occurrence, in the Ironton district, is located on the creek about one-fourth of a mile west of Ironton.

Molybdenite has been reported from Poughkeepsie Gulch and from the Sneffels region.

PITKIN COUNTY

A deposit of molybdenite, associated with pyrite and small amounts of molybdite, is located near the head of Lincoln Gulch, 20 miles southeast of Aspen.

The molybdenite is found in quartz veins which cut the granite country rock of the district.

SAN MIGUEL COUNTY

Worcester[54] has described two molybdenum claims located on the west side of Nevada Gulch, about one mile southeast of Ophir.

OIL AND GAS

DELTA COUNTY

An anticlinal structure has been reported near Hotchkiss. Several oil seeps and gas springs are also known to exist in the district. Oil and gas have not been found in commercial quantities in Delta County.

MONTROSE AND SAN MIGUEL COUNTIES

An open anticline occurs near the border of Montrose and San Miguel counties, southwest of Naturita. A trace of oil and gas was found in a well in San Miguel County, south of Naturita.

MESA COUNTY

The De Beque oil field covers an area only a few square miles in extent. Wells have been drilled along the Grand River near De Beque; up Roan Creek for a distance of 2 miles, and on the terrace to the north and northwest of the town.

[54]Worcester, P. G., Molybdenum deposits of Colorado: Colo. Geol. Survey Bull. 14, p. 86, 1919.

Only a small amount of oil and gas has been produced by the various wells in the field, and this has not been put to commercial use.

The drilling in the district has not been done along the axis of the structure, but off to one side. This field should not be condemned without properly drilling it out, as it still shows possibilities.

ONYX

MESA COUNTY

Onyx occurs in several areas west of Fruita, near the Colorado-Utah line. Some of this material takes a high polish and is suitable for ornamental purposes.

PRECIOUS STONES

Amethyst quartz is found in the Elk Mountains, in Gunnison County, and on Henson Creek, in Hinsdale County. Chalcedony of gem variety is found in Ouray and Gunnison counties. A gem variety of epidote has been found near Italian Mountain, in Gunnison County. Garnet (grossularite) is found on Italian Mountain, in Gunnison County.

PYRITE

EAGLE COUNTY

Pyrite deposits of considerable size have been developed in the Red Cliff district. Pyrite from this district has been shipped to the sulphuric acid plant of the Western Chemical Company, at Denver.

SILVER[55]

GUNNISON COUNTY

Silver is the principal metal produced in the Quartz Creek district, 3 miles north of Pitkin; in the Rock Creek and Crystal districts near Marble; and in the Ruby district near Floresta. The production of silver in Gunnison County in 1919 was valued at $18,100. From 1873 to 1917 the silver production was valued at $4,816,026.

HINSDALE COUNTY

In the district around Lake San Cristobal, the metallic ores are found in veins which occur in the Tertiary volcanic rocks. The predominant metal of the district is silver.

[55]See Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician. U. S. Geol. Survey.

During 1919, silver to the value of $17,726 was produced in Hinsdale County. The total value of the silver produced in the county from 1875 to 1917 was $4,428,964.

PITKIN COUNTY

Silver is predominant among the metals produced in the Lincoln mining district, 15 miles southeast of Aspen, and in Aspen.

During 1919, $718,333 worth of silver was produced in Pitkin County. The production of silver from 1880 to 1917 was valued at $70,012,602.

SAN MIGUEL COUNTY

The silver ores of the Mount Wilson district occur in veins in the Cretaceous sediments and Tertiary volcanics. The Mount Wilson mining district is located 12 miles south of Newmire.

SLATE

GUNNISON COUNTY

J. C. Bailar[56] reports the presence of slate near Gunnison, as follows:

"A large deposit of slate has been opened near Gunnison. The plates are large, smooth and of good texture, superior to most of the slate found on the market."

OURAY COUNTY

A large section of slates is exposed in the Uncompahgre Canyon, near the mouth of Bear Creek. So far as yet opened the slates of this area are very badly shattered, and consequently are of little commercial value. But further development may prove the existence of better material.

SULPHUR

GUNNISON COUNTY

A small amount of sulphur was mined and refined at the Vulcan mine, 12 miles southeast of Iola. No data are available, however, regarding the amount of sulphur mined, or the time of shipment.

The main ore bodies occur in a chimney between walls of sericite schists.[57] "In the Vulcan mine at 100 feet the walls on either

[56]Bailar, J. C., The non-metallic minerals of Colorado: Colorado School of Mines Bienn. Rept., p. 37, 1910.

[57]Lakes, Arthur, Gunnison region (Rocks and their relation to ore deposits in Mammoth and Vulcan mines): Coll. Eng., vol. 16, p. 280, 1895-6.

side of the main brecciated, dark, opaline zone, were of yellow granulated sulphur, said to be 15 feet thick.'' The sulphur then grades into loose pyrites, below which is found solid massive pyrite.

Hot ascending solutions have undoubtedly dissolved out the silica of the surrounding rocks, and after transporting the material in solution, it has been deposited in the form of opaline silica. The sulphur may have been due to the desulphurizing of the pyrite lower down, in which action the sulphur was set free, or it may be the result of the precipitation of sulphur from the ascending sulphurated hydrogen gases.[58]

DELTA COUNTY

Sulphur has been reported as occurring near the mouth of the Black Canyon of the Gunnison above Delta. No information concerning this deposit (Smith, P. S. Mineral Resources of the United States: U. S. Geol. Survey, 1917, pt. II, p. 20) is available.

MESA COUNTY

Smith[59] reports the occurrence of a deposit of sulphur in Mesa County, near Grand Junction. No data are available concerning this deposit.

TUNGSTEN

GUNNISON COUNTY

Considerable quantities of tungsten (hübnerite) are found in a large quartz vein in the Ida May claim, on Gold Hill, north of Pitkin.[60] Some tungsten ore was shipped from this property during 1916-1917.

Rich streaks of hübernite have also been found in the Monitor vein. This is undoubtedly a continuation of the Ida May vein.

ZINC

SUMMIT COUNTY

Large amounts of zinc are found in the ores of the Breckenridge and Kokomo mining districts. The production of zinc during 1919 amounted to $342,326. The value of the production from 1860 to 1917 was $8,270,063.

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[58]Lakes, Arthur, Gunnison region (Rocks and their relation to ore deposits in Mammoth and Vulcan mines): Coll. Eng., vol. 16, p. 280, 1895-6.

[59]Smith, P. S., U. S. Geol. Survey, Mineral Resources for 1916, pt. II, p. 407.

[60]Worcester, P. G., Molybdenum deposits of Colorado: Colo. Geol. Survey Bull. 14, pp. 63-64, 1919.

EAGLE COUNTY

During 1919, Eagle County produced 2,929,798 pounds of zinc, valued at $205,086. The total production of the county from 1879 to 1915 was valued at $9,463,104.

GUNNISON COUNTY

The value of the zinc produced in Gunnison County during 1919 amounted to $154,620. The total production from 1873 to 1917 sold for $960,087.

SAN JUAN COUNTY

The value of the zinc produced in San Juan County during 1919 was $121,944. The total production from 1873 to 1917 sold for $2,013,632.

SAN MIGUEL COUNTY

The zinc produced in San Miguel County during 1919 was valued at $40,022. The total production from 1875 to 1917 was valued at $1,199,375.

CHAPTER III

MINERAL DEPOSITS

OF

SOUTHWESTERN COLORADO

BISMUTH

Bismuth occurs in commercial quantity in at least two mines in the La Plata Mountains.

BUILDING STONE

LA PLATA COUNTY

Granite.—According to Burchard,[61] some granite is quarried near Durango. No information is available, however, concerning the production or output of this quarry.

SAN JUAN COUNTY

Quartz monzonite from Anvil and Kendall Mountains has been used for building purposes in the town of Silverton.

LA PLATA COUNTY

Sandstone is being quarried near Durango. The entire product is used in building operations in the immediate vicinity.

CLAYS

Very little is known of the clay resources of western Colorado; for the reason that no systematic investigation has been made and but little has been published on them. Up to the present time the demand for clay products has been so small that no effort has been made to create an interest in the clay industry.

SOUTHWESTERN COLORADO

The clays of the area may be classed as clay shales, plastic clays, and fire clays.[62]

[61]Burchard, E. F., U. S. Geol. Survey Mineral Resources for 1912, p. 813.
[62]Shaler, M. K., and Gardner, J. H., Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 315, p. 296, 1906.

The clay shales include the thick shales of the Mancos and Lewis formations, and many thinner beds found associated with the coal beds of the Mesaverde and Laramie formations.

The plastic clays include alluvial beds, river terrace clays, adobe clays, and in fact all shales or clays derived from the weathering and decomposition of clay shales. Deposits of this kind are being worked at Glenwood Springs, Aspen, and Grand Junction. In all these cases the less sandy clays are likely to be found back from the river.

Fire clays of different grades are found interstratified with the sandstones, shales, and coals of the Mesaverde formation.

In the southwestern part of the state shales of various parts of the Mancos formation are well suited for the manufacture of brick. The shales, as a whole, make ordinary brick of good quality. Certain strata, however, will furnish materials for the manufacture of semi-refractory brick.

The Lewis shales, which in western Colorado lie between the Mesaverde and Laramie formations, appear suitable for the manufacture of ordinary brick. They are very similar to the shales of the Mancos formation, but so far no tests have been made to show their suitability for the manufacture of clay products as other shales and clays of known value are readily available.

Careful prospecting will undoubtedly show the presence of a considerable amount of fire clay in both the Dakota and Mesaverde formations.

At Durango, ordinary red brick have been manufactured from strata about 100 feet below the lowest coal seams in the Mesaverde formation, and semirefractory bricks, suitable for boiler linings, have been made from a clay bed just below the lowest coal bed of the Mesaverde formation.

Many of the shales could be mixed with the limestones of the district in the manufacture of Portland cement.[63]

At present the market for clay and shale products in this district is local, as the freight rates will not permit their shipment to outside points. This condition has hindered the development of the industry, regardless of the fact that enormous bodies of suitable material are available in the district.

[63] Shaler, M. K., and Gardner, J. H., Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 315, p. 298, 1906.

COAL

SOUTHWESTERN COLORADO

The Mesaverde is the principal coal-bearing formation in southwestern Colorado. Some coal, however, is found in the Laramie formation, and some in the Dakota.

Outcrops of the coal-bearing strata of the Mesaverde formation have been traced from Durango, La Plata County, to a point near Mancos, in Montezuma County. Between Durango and Monero, New Mexico, the Mesaverde formation outcrops almost continuously, but not a single workable bed on the northeast side of the basin has been found for a distance of 60 miles along the outcrop.

The Mesaverde formation is productive in various parts of western Montezuma County, and small amounts are being mined for local purposes. Some coal is being mined near Cortez in the central part of the county.

West of Durango, the coals of the Laramie formation are subbituminous in character. Those of the Mesaverde formation are very good bituminous. The coal mined at Porter is a very good coking coal, and has been made into coke at Porter and Durango. The coke produced is used locally in the smelting industry.

East of Durango the Mesaverde measures are barren, but some coal is mined from the Laramie formation. This coal is of a low grade and might be classed as sub-bituminous.

Eight mines in La Plata County produced 141,040 tons of coal during 1918. Five mines in Montezuma County produced 1,927 tons of coal during the same period.

The Dakota coal is commonly of low grade, and the seams are usually thin. A few mines or pits are opened for purely local use.

FLUORSPAR

DOLORES COUNTY

Fluorspar is found sparingly as a gangue mineral in the ores of the Rico mining district. It is abundant in the displacement ore bodies of the Blackhawk mine and Fortune and Duncan prospects.[64]

LA PLATA COUNTY

In the La Plata mining district, fluorite occurs as a gangue mineral, associated with quartz, calcite, and rhodochrosite.[65]

[64] Cross, Whitman, and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Rico folio (No. 130), p. 15, 1905.

[65] Cross, Whitman, Spencer, A. C., and Purington, C. W., U. S. Geol. Survey Geol. Atlas, La Plata folio (No. 60), p. 13, 1899.

SAN JUAN COUNTY

Small amounts of flourspar occur as a gangue mineral in the ores of the district. Colorless, to lilac, and deep green flourspar is found in the Aspen, Anglo Saxon, and Dakota mines, while smaller amounts are found in the ores of many other mines.[66]

The mineral does not occur in sufficient quantity to be commercially important, and it is too badly fractured to be used for optical purposes.

GOLD[67]

LA PLATA COUNTY

Gold is the most important metal in the ores of the district near California, 14 miles northwest of Durango, and in the West Needle Mountains district, 25 miles northeast of Tacoma. La Plata County produced only $6,202 worth of gold in 1919, but the production of La Plata and Montezuma counties from 1878 to 1917 was $3,470,943. La Plata County produced by far the greater part of this amount.

MONTEZUMA COUNTY

A small amount of gold is produced in the district 12 miles northeast of Mancos. This placer district is known as the East Mancos mining district.

SAN JUAN COUNTY

During 1919, San Juan County produced $153,674 in gold. From 1873 to 1917 the production amounted to $21,778,759.

GRAPHITE

SAN JUAN COUNTY

Warren C. Prosser[68] reports the finding of a large deposit of low grade graphite near the divide between Cascade Creek and the south fork of Mineral Creek. This deposit lies in the extreme western part of San Juan County, near the junction of Dolores, San Miguel, and San Juan counties.

[66]Cross, Whitman, Howe, Ernest, and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Silverton folio (No. 120), p. 29, 1905.

[67]See Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician, U. S. Geol. Survey.

[68]Personal communication January 11, 1912. Warren C. Prosser, Silverton, Colorado.

GYPSUM

RICO DISTRICT

In the Rico quadrangle gypsum occurs well down in the Hermosa formation.[69] At Newman Hill a bed of rock gypsum 30 feet thick occurs locally above one of the black shales in the lower part of the Hermosa formation.

DURANGO DISTRICT

Near Hermosa Creek north of Durango, the lower part of the Hermosa formation above the limestone is made up of green sandstones and shales with bands of gypsiferous shales.[70]

Gypsum also occurs in numerous localities throughout the western and southwestern parts of the state. These occurrences have not been taken up in detail, because of the lack of definite information concerning them or because of the unimportance of the occurrence.

No gypsum has been mined on the "Western Slope" during the past few years. The demand for the finished product is not large, and the high freight rate to "Eastern Slope" markets does not permit its competition with gypsum mined east of the range.

RIO BLANCO COUNTY

According to Henderson, large deposits of gypsum[71] occur in the earlier formations of upper White River Valley.

SOUTHWESTERN COLORADO

A thick bed of gypsum occupies the whole head of Big Gypsum Valley and extends along the north side of the valley to the Dolores River. It reappears down the river at the mouth of Little Gypsum Valley and extends some distance up that valley, especially on the north side. The deposit is overlain by a crumpled limestone, and this is overlain unconformably by the Dolores sandstone and conglomerates. The unconformity may represent Cutler time. In places a rich Pennsylvanian fauna occurs a distance above the gypsum. The area covered by gypsum in the two valleys is probably between 20 and 30 square miles. The mineral occurs as massive white gypsum in beds from 5 to 10 feet thick throughout a series of strata between 200 and 300 feet thick. Weathering has formed impure gypsite.

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[69]Cross, Whitman, and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Rico folio (No. 130), p. 3, 1905.

[70]Cross, Whitman and Ransome, F. L., U. S. Geol. Survey Geol. Atlas Rico folio (No. 130), p. 3, 1905.

[71]Henderson, Junius, Scientific expedition into northwestern Colorado in 1909. Univ. Colo. Studies, vol. 7, pp. 111-112, 1910.

In East Paradox Valley gypsum covers about 8 square miles, and in West Paradox about one-half square mile. In these valleys the gypsum is associated with limestones and shales and is overlain by red shales and shaly sandstone.

In Sinbad Valley gypsum covers about 7 square miles and is associated with limestone and shale. Cross and Howe believe the gypsiferous series to be the same as that[72] which Peale[73] regarded as Permian. They think the beds may be Cutler.

Coffin[74] reports the presence of an intricately folded and faulted series of limestone, gypsum and shale appearing in the bottoms of Sinbad, Paradox, and Gypsum valleys. Fossils from this district prove that at least a part of this complex belongs to the Pennsylvanian division of the Carboniferous, and is equivalent to the Hermosa of the San Juan Mountains.

From the various views expressed, and from the field relations which exist, it would seem probable that the beds in all this region are Permian or late Pennsylvanian.

IRON

SAN JUAN COUNTY

Deposits of bog iron occur in the swampy ground along Mineral Creek and in Ironton Park. Some of this ore was mined and used as a flux in the smelter formerly operated at Silverton.

LIMESTONE

LA PLATA COUNTY

A very high grade limestone is quarried at Rockwood, north of Durango. Although the limestone is burned, or shipped as a flux, it might easily be used with the shales of the Mancos formation in the manufacture of cement.

SAN JUAN COUNTY

A small amount of limestone was taken from a quarry about one and one-half miles south of Silverton on the east bank of the Animas River. This limestone was used as a flux in the early day smelters of the Silverton district.

[72]Cross, W. and Howe, E., The Red Beds of southwestern Colorado: Geol. Soc. Am. Bull., vol. 16, pp. 447-498, 1905.

[73]Peale, A. C., Geological report on the Grand River district: Hayden Survey, Tenth Ann. Rept., pp. 167-168, 1878.

[74]Coffin, R. C., Preliminary statement from Bull. 16 on the carnotite area of southwestern Colorado: Colo. Geological Survey, p. 8, 1920.

MANGANESE

SAN JUAN COUNTY

Rhodonite and rhodochrosite frequently occur as gangue minerals in the metalliferous veins of the district. No deposits of commercial value are known to occur in the county.

A small deposit of manganese has been located about eight and one-half miles east of Needleton, on the east slope of Hope Mountain.

DOLORES COUNTY

Manganese occurs in the form of rhodochrosite (manganese carbonate) in many of the ores of the Rico district. The mineral is frequently mixed with quartz and fluorite.

MERCURY

LA PLATA COUNTY

Lakes[75] reports the finding of a peculiar occurrence of native mercury, free gold, and telluride minerals near Trimble Springs.

Cinnabar is also reported as occurring in the sandstones of La Plata County, and in ores of the Ruby claim south of Cumberland Peak.[76]

MINERAL SPRINGS

ARCHULETA COUNTY—The Pagosa Springs are a noted group about which a resort town is built.

DOLORES COUNTY—There are excellent mineral springs within and about Rico.

LA PLATA COUNTY—The Trimble Springs on the Animas are well developed as a resort. The Pinkerton Springs are also on the Animas but are not well developed for use.

SAN JUAN COUNTY—A mineral spring is located about 4 miles up South Mineral Creek. Other springs occur in the county.

MOLYBDENUM

LA PLATA COUNTY

About a dozen shallow shafts have been sunk on molybdenum-bearing quartz veins in the gray granite country rock of the dis-

[75]Lakes, Arthur, Mg. Rept., vol. 54, pp. 389-390, 1906.
[76]Schrader, F. C., Stone, R. W., and Sanford, S., Useful Minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 81, 84, 93, 1917.

trict on East Silver Mesa. The district lies about nine miles from Needleton and within 2,000 feet of Lake Lillie.

Molybdenite has also been reported from the Vallecito Basin, about 7 miles from Needleton. This occurrence is at an elevation of about 12,600 feet.

MONTEZUMA COUNTY

It is reported that molybdenite has been found at Giles Mountain, near Mancos.

SAN JUAN COUNTY

Molybdenite has been found in the Hidden Treasure and Gold Finch groups of claims, about half a mile south of Chattanooga.

The Gold Finch group lies just west of Mineral Creek. Surface cuts show the occurrence of the vein for 750 feet west of the creek. The Hidden Treasure group lies east of Mineral Creek and shows outcrops of ore for 800 feet along the vein.

Molybdenite has been reported as occurring two and one-half miles south of Chattanooga, on the east side of Mineral Creek; on the north side of South Mineral Creek about a mile from the mouth of the gulch; on the southwest slope of Bear Mountain about four miles west of Silverton, and near Molas Lake in Cascade Basin.

Ransome[77] reports the occurrence of molybdenite in the Sunnyside Extension mine, where it has been mistaken for graphite. Here some of it contains free gold.

NATURAL COKE

LA PLATA COUNTY

Natural coke has been found at several localities in the Durango district.

OIL AND GAS

ARCHULETA COUNTY

Several structures and oil seeps have been located in the eastern part of the county. Lee[78] says the Navajo oil spring is the best known in the county. This spring issues from a crevice in the base of the Fox Hills sandstones on the south side of Navajo Creek, a short distance from the foot of the Conejos range.

[77]Cross, Whitman, Howe, Ernest, and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Silverton folio (No. 120), p. 30, 1905.

[78]Lee, H. A., Colorado State Bur. Mines Rept. for 1901-1902: p. 17, 1903.

MONTEZUMA COUNTY

Several anticlines have been found in Montezuma County. Some gas was encountered in a well drilled near Toltec.

POTASH

DOLORES COUNTY

A deposit of alunite has been found near Rico. Considerable attention has been given to this deposit, but no great amount of development work has been done.

PRECIOUS STONES

SAN JUAN COUNTY

Several varieties of garnet, as well as calcite and wollastonite are found in an old limestone quarry about one mile southeast of Silverton.

Rhodonite occurs in large sized pieces of excellent color in the Sunnyside mine at Eureka. A considerable amount of this material has already been cut for the manufacture of jewelry

It is reported that a few crystals of topaz have been found in San Juan County.

PYRITE

LA PLATA COUNTY

It is reported that large bodies of pyrite have been developed in the La Plata district. No data are available concerning the exact location or size of these deposits.

SILVER[79]

DOLORES COUNTY

Silver is the predominant metal produced in the Dutton mining district, sixteen and one-half miles northwest of Rico.

In the Rico district the main ore bodies occur as veins, replacements, and stockworks in the pre-Cambrian and Palezoic sediments. The production of silver in Dolores County during 1919 amounted to $36,631.

The total value of the silver produced in Dolores County from 1879 to 1917 amounted to $11,468,112.

SULPHUR

MONTEZUMA COUNTY

A large deposit of low-grade sulphur ore has been reported as occurring about 20 miles east of Dolores. Very little work has

[79]See Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, pp. 134-157, 1912. Statistics compiled by C. W. Henderson, Statistician, U. S. Geol. Survey.

been done on the deposit, and no sulphur has been shipped up to the present time. Data are lacking as to nature of the occurrence and the size of the deposit.

TUNGSTEN

SAN JUAN COUNTY[80]

R. D. George[81] reports the presence of tungsten in San Juan County as follows:

"Hübnerite is found in a number of mines and prospects near Gladstone, north of Silverton; in the Tom Moore lode, one and one-half miles above Eureka, on the Animas; and in three or more properties on the slopes of Sultan Mountain. It was found in the Royal Albert vein in the Uncompahgre district, Ouray County."

The occurrences of tungsten in Dry Gulch, a tributary of Cement Creek, below Gladstone, have proven of considerable extent. Several shipments of high grade concentrates were made from this locality in 1915-1916.

During the tungsten excitement of 1915-1916 a number of new deposits were developed in the Silverton district. Production was stopped, however, with the return to normal prices.

URANIUM[82]

SOUTHWESTERN COLORADO

By far the greater part of the world's supply of uranium and radium is produced from the deposits of carnotite in southwestern Colorado and southeastern Utah.

In Colorado, the carnotite production is limited, almost entirely, to the McElmo formation and rather definitely to certain beds or zones within the lower half of the formation. The most important carnotite zone is located from 275 to 325 feet above the base of the formation, in a massive white cross-bedded sandstone. A second zone extends from 60 to 125 feet above the base of the formation. The carnotite in this zone is found in a sandstone very similar to the sandstone of the upper zone.

In the faulted areas of Gypsum Valley some carnotite stains have been found in the Carboniferous and Dolores beds which occur at a considerable depth below the McElmo formation. In

[80]Cross, Whitman, Howe, Ernest, Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Silverton folio (No. 120), p. 30, 1905.

[81]George, R. D., The main tungsten area of Boulder county, Colorado: Colo. Geol. Survey First Ann. Rept., pp. 55-56, 1908.

[82]For a full discussion of the Carnotite deposits of southwestern Colorado see: Coffin, R. C., Preliminary statement from Bulletin 16 on the carnotite area of southwestern Colorado: Colo. Geol. Survey, 1920.

McElmo Canyon a vanadium-bearing sandstone containing small amounts of uranium was found near the top of the Dolores formation.

According to Coffin,[83] the term "carnotite ore" has been applied to ores of different sorts, often including any uranium-bearing material in the district. Although carnotite is a common mineral in the ore, its value may depend upon one or more of several uranium and vanadium minerals. The types of ore include the following:

"1. Impregnated sandstones—the uranium-vanadium minerals cementing the sand grains.

"2. 'Spotted ore'—the ore occurs in sandstones or shaly sandstone as dark blotches wherein vanadium-bearing minerals predominate; as almond-shaped pieces and small fragments of shale and carbonaceous material speckled with carnotite.

"3. Nearly pure carnotite—in seams, crusts, irregular vugs, and elongated masses called 'bug holes.'

"4. Replacements of wood—ore often of extremely high grade."

The workable deposits of ore may be classed as follows:[85]

"1. Rather continuous bodies, in plate-like masses and lenses, but of irregular outline.

"2. Discontinuous bodies, consisting of seams, crusts, bunches, and irregular pockets of many sizes and shapes.

"3. Cylindrical masses, commonly called 'trees' or 'logs'; ores frequently of very high grade."

During 1919 the demand for vanadium gave an added stimulus to carnotite mining. Prices were advanced somewhat and there was also a lowering of the mining uranium and vanadium content requirements.

It is exceedingly difficult to obtain information as to the amount of carnotite mined, since much of the ore that is mined does not reach the point of treatment for many months.

Coffin[86] estimates that the carnotite mined in southwestern Colorado during 1919 was equivalent to 9,550 tons of ore having a 2 per cent uranium oxide (U_3O_8) content. The vanadium oxide (V_2O_5) content of this ore averaged between 3.5 and 4.3 per cent.

[83]Coffin, R. C., Preliminary statement from Bulletin 16 on the carnotite area of southwestern Colorado: Colo. Geol. Survey 1920.

[85]Coffin, R. C., Preliminary Statement from Bull. 16 on the carnotite area of southwestern Colorado: Colo. Geol. Survey 1920.

[86]Coffin, R. C., Preliminary statement from Bull. 16 on the carnotite area of southwestern Colorado: Colo. Geol. Survey 1920.

The estimate does not represent the tons of ore actually handled, as a large part of this amount was "mill ore" whose uranium oxide (U_3O_8) content was 1 per cent or less.

VANADIUM[84]

SOUTHWESTERN COLORADO

The vanadium deposits at Vanadium (formerly Newmire) have been the source of much of the vanadium produced in the district.

The ore is made up of a green, fine grained sandstone impregnated with roscoelite, and is easily mined. The rock must carry about 3 per cent vanadium in order to be of shipping grade. It is necessary to select the material carefully as the percentage of vanadium in most of the vanadiferous sandstones is less than 1 per cent.

VOLCANIC ASH

LA PLATA COUNTY

Deposits of volcanic ash suitable for abrasive purposes have been reported from near Durango[87] in La Plata County. These deposits consist of three isolated beds of ash, all lying within a radius of 4 miles of Durango.

One bed of ash is located at the east end of the dry valley north of Animas City Mountain, on the shoulder of the southward-facing spur. A second bed is located opposite the west end of the same valley, while a third lies nearly east of Durango on the east slope of Florida Mesa.

All three of the beds are at approximately the same elevation and appear to have been deposited under similar conditions. The beds appear to be lens shaped, occupying irregularities in the former bed-rock surface. One lens is over 150 feet long and 15 feet wide, while a second is 100 feet long and from 25 to 50 feet thick.

In age the deposits are probably Pleistocene. However, no fossils have been found, and the age has been judged mainly from the relations of occurrence.

A small amount of the ash has been used locally, but no great effort has been made to create an outside market for the product.

[84]Hess, Frank L., U. S. Geol. Survey, Mineral Resources for 1911, pp. 949-950.

[87]Woolsey, L. H., Volcanic Ash near Durango, Colorado: U. S. Geol. Survey Bull. 285, pp. 476-478, 1905.

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